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**ACCURACY OF AXIS ANGLE
DIFFERENCE JUDGEMENTS
AT THE BOUNDARIES OF A
PRESCRIBED CATEGORY
SYSTEM**

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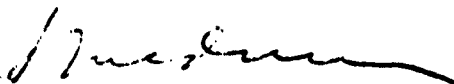
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BRIEF

During the summer of 1961, students at the Fleet Anti-Submarine Warfare School, San Diego, were tested on their ability to make target axis angle difference judgments utilizing the angles at the boundaries of the Navy Electronics Laboratory category system as standard stimuli. It was found that about 50% of the judgments were corrected at about ± 4 to 5 degrees (p. 7). In comparison to absolute angular categorization, the inclusion of a standard comparison stimulus considerably increased accuracy (p. 9).

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ACCURACY OF TARGET AXIS ANGLE DIFFERENCE JUDGMENTS AT THE BOUNDARIES OF A PRESCRIBED CATEGORY SYSTEM

A. Background

Critical to the accurate classification of targets in existing target classification systems is adequate perception of certain acute angles within categories established by the systems. An earlier report (1) indicated that the existing literature was inadequate for answering the operational questions posed by this type of stimulus, and described a study in which subjects performed rather poorly when required to classify absolute angular judgments by means of the Navy Electronics Laboratory (NEL) category system (2). To test the limits of the ability of operators to make target axis angle discriminations, the following study was conducted.¹ Utilizing the boundary angles between the NEL categories as standard stimuli, measures of the accuracy of angular difference judgments were obtained with the goal of answering the following specific questions:

1. How accurately can target axis angle differences be judged?
2. Is there any predominant direction to the error pattern?
3. Are the near threshold axis angle judgments inferior or superior to the near threshold absolute category judgments required in the preceding study?

B. Procedure

1. Subjects

The subject sample consisted of 78 students in Course C-560G for sonar operators at the Fleet Anti-Submarine Warfare School, San Diego. Testing was conducted after target classification training had been completed.

2. Apparatus and Test Materials

The target axis angles were simulated by means of 35 mm, slide projected photographs of line drawings of a PPI scope with bearing cursor-target axis intersections. It can be assumed that these stimuli constitute an idealized presentation and that the "visual noise" associated with real scope presentations will tend to degrade performance below that here reported.

¹The study here reported is part of a series of investigations relating to the ability of human observers to assess certain types of displayed information important to the target classification problem.

A test item consisted of two scope simulations side by side. The bearing cursor was three fourths the length of the scope radius and always bore 030 degrees relative from the vertical. The target axis was one fifth the length of the bearing cursor; its length equally distributed on either side of its point of intersection with the cursor. In every case, the drawing on the left was designated "A" and the one on the right "B". Figure 1 illustrates a typical test item.

Presentation of test items was by means of a Revere 888-D, 35 mm slide projector, which provided an automatic timed viewing interval of approximately 8 seconds. On request, items were re-presented if any subject felt the time to be inadequate. Such requests were very rare.

Four standard angles were used corresponding to the four boundary points between the categories of angle size employed in the NEL category system. They were 19.5, 59.5, 74.5, and 84.5 degrees. Each of the standard angles was paired with angles ranging away from it in 1 degree intervals in either direction for a distance of 9 degrees, except in the case of the standard angle of 84.5 degrees where the upper bound of 90 degrees limited the range upward to 5 degrees.

The test items were formed into four series; each series consisting of all items utilizing a given standard angle. Within each series the appearance of the standard angle on the left under "A" or the right under "B" was determined randomly and the order of presentation of items within the series was randomized. The series were presented consecutively from series 1 representing the lowest standard angle to series 4 representing the highest for half the subjects and in the order 3, 4, 1, 2 for the other half.

Before testing, the subjects received the following instructions:

"Please turn to the first page of the answer booklet and write your name, last name first, your class, and the date.

"You are about to see a series of slides which look like this. (Sample slide is projected on the screen). Now look at your answer sheet. You will notice that it has three columns, one headed 'A greater than B', one 'A equal to B', and one 'A less than B'.

"On every slide the display on the left is labeled 'A' and the one on the right is labeled 'B'. You are to judge whether the acute angle formed by the intersection of the two straight lines in 'A' is greater than, equal to, or less than the acute angle formed by the intersection of the two straight lines in 'B' (the acute angles in 'A' and 'B' are pointed out on the screen). You will recall that an acute angle is less than 90 degrees--or less than a right angle.

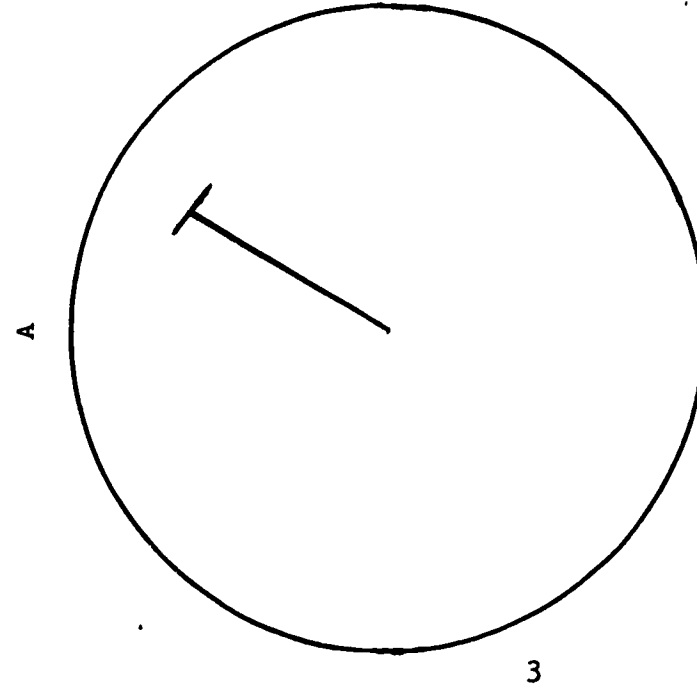
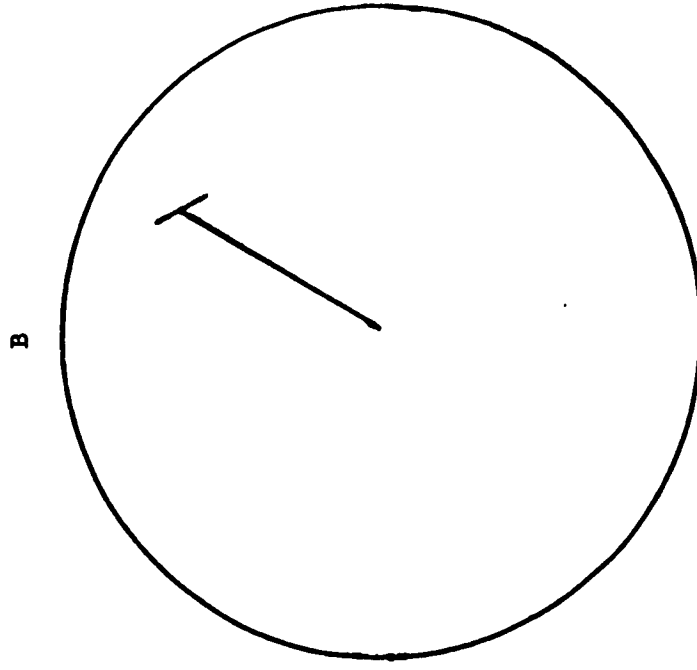


Fig. 1. Representative test item.

"In the sample now on the screen the correct answer would be 'A greater than B'. In the next sample (second sample slide is projected) the correct answer would be 'A less than B'.

"Commencing with the next item that is projected please record your answer by placing an 'X' in the appropriate column and line on the answer sheet. The item number that you check on the answer sheet must correspond with the number that appears in the upper left corner of the screen. (number in upper left corner is pointed out).

"Are there any questions?

"Remember, in every case you compare 'A to B', that is: 'A greater than B'; 'A equal to B'; or 'A less than B'.

"The next slide is item 1."

C. Results

The data were initially tabulated in terms of the number of subjects judging each variable stimulus as "greater than", "equal to" or "less than" the standard with which it was compared. The data were converted to proportions and plotted for each standard stimulus separately and for all combined. Inspection of the curves indicated that the "greater than" and "less than" proportions formed approximate ogives and the "equal to" proportions formed approximate normal curves around the standard stimuli. These results are to be expected in the constant stimulus method with three categories. Following recommended procedure (4, p. 205-206) the proportions of the ogives were converted to "Z" score equivalents on each side of the standard and averaged to supply two points for constructing the best fitting straight lines. As an illustration, Figure 2 shows the proportional distributions for the combined boundary data, and Figure 3 shows the corresponding best fitting straight line "Z" score transformations of the "greater than" and "less than" functions. Similar "Z" score transformation functions for each of the boundary stimuli separately are found in Appendix A. The intersection of the two straight lines gives the stimulus value corresponding to the point of subjective equality and comparison with the actual standard stimulus provides a measure of any constant error in the judgments. By erecting verticals from the base line to the points of intersection with the "Z" score functions at the $Z=0.0$ point, the upper and lower difference thresholds are obtained and the area enclosed by them constitutes the interval of uncertainty. The interval of uncertainty may be interpreted as the interval of angular values in which neither greater nor less judgments have a clear majority. Actually, an uncertainty interval can be calculated for any proportion of judgments. At the

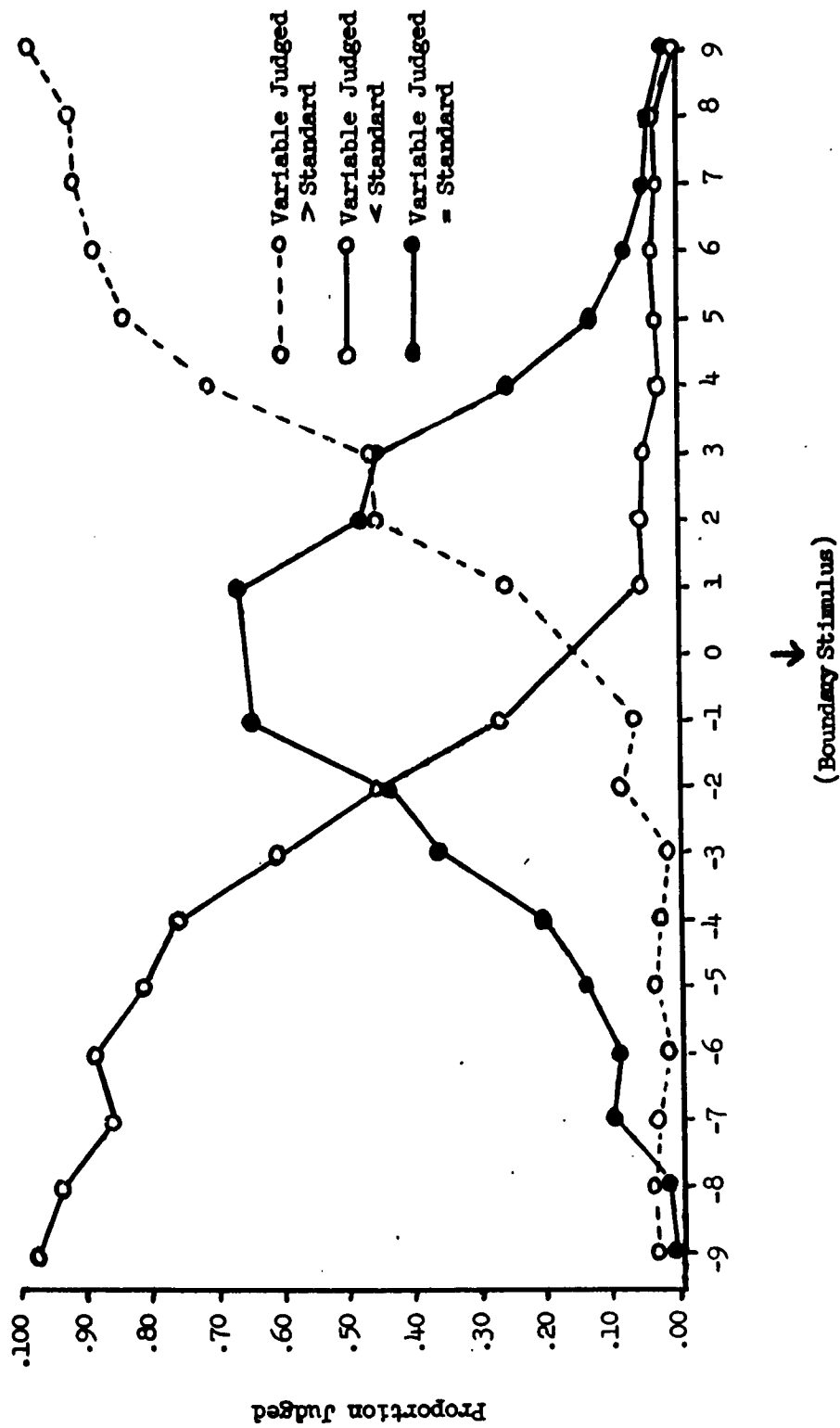
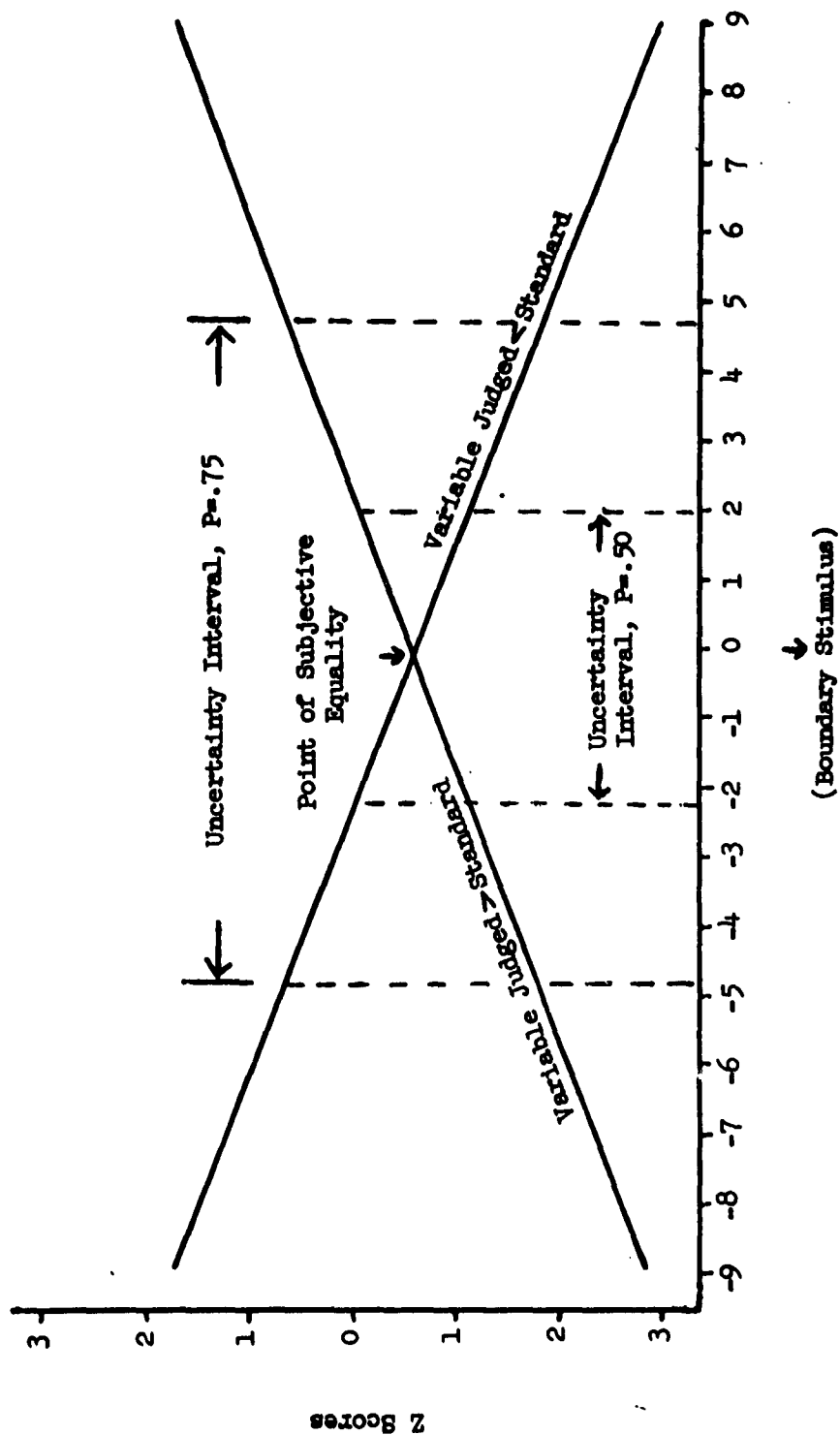


Fig. 2. Proportion of judgments of variable stimulus greater, less, and equal to boundary stimulus as a function of angular difference (all boundaries combined).



Variable-Boundary Stimulus Difference in Degrees

Fig. 3. Average Z score equivalent of proportion of judgments greater and less, uncertainty intervals, and point of subjective equality (all boundaries combined).

Z=0.67 point, it would indicate the limits beyond which 75% of the judgments are correct on either side of the standard. This has been done for the combined boundary data shown in Figure 3. Similar Z score functions have been prepared for each of the boundary stimuli separately and are found in Appendix A. From Figure 3 and Appendix A, the reader can obtain uncertainty intervals for any percentage of correct judgment in which he may have an interest. Table 1 presents the 0.0 and 0.67 Z score uncertainty intervals and the location of the points of subjective equality for each boundary stimulus separately and for all combined. Figure 4 presents the same data graphically.

TABLE 1
Levels of Uncertainty and Points of Subjective Equality
in the Judgment of Target Axis Angle Differences

	Boundaries				All Boundaries
	1 (19.5°)	2 (59.5°)	3 (74.5°)	4 (84.5°)	
Interval of Uncertainty Z=0.0	3.3°	5.7°	3.8°	4.0°	4.2°
Interval of Uncertainty Z=0.67	7.7°	12.0°	8.5°	8.1°	9.5°
Point of Subjective Equality	19.6°	59.2°	74.2°	84.3°	-0.1

It can be seen that except for Boundary 2, the values are quite similar in terms of uncertainty levels. The points of subjective equality are quite near the standard stimuli, indicating no major degree of constant error.

In order to compare the results of this study with the earlier one which required absolute categorized judgments, the stimuli that were common to both studies were averaged as to the percentage correctly categorized versus percentage correctly discriminated, and are presented in Table 2. For this purpose, the "equal to"

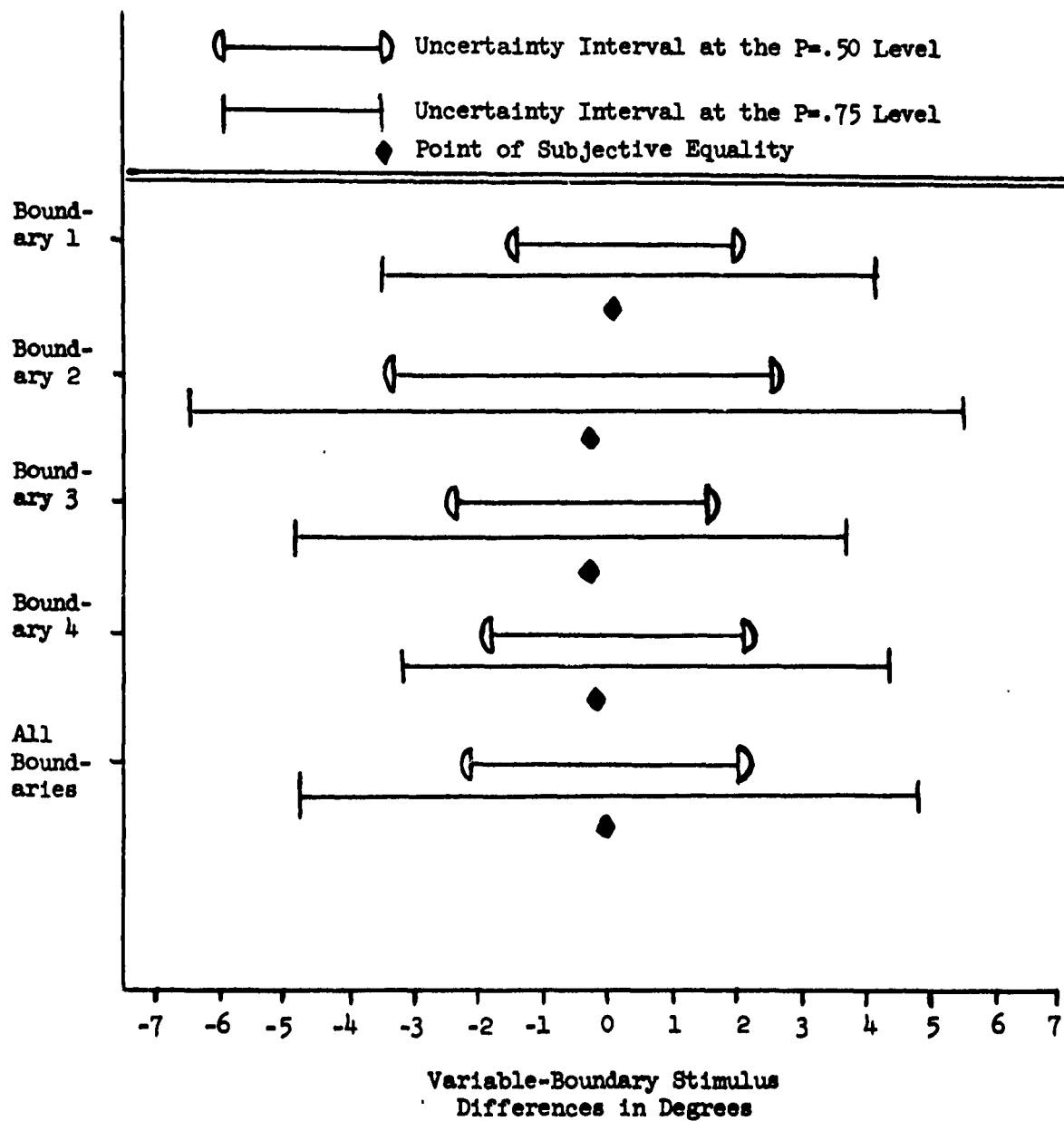


Fig. 4. Uncertainty intervals and points of subjective equality for each boundary stimulus and for all combined.

judgments in the present study were disregarded, which is equivalent to allotting them to the "greater than" and "less than" categories in proportion to the judgments falling into each. Guilford (3) indicates that this is usually a reasonable means for converting three category into two category data with minimum distortion.

TABLE 2
Comparative Accuracy of Two Modes of Judging Angular Extent

	<u>Per Cent Correct</u>	
	<u>Absolute Angle Classification</u>	<u>Relative Angle Judgment</u>
Boundary 1	82	96
Boundary 2	49	88
Boundary 3	48	93
Boundary 4	66	94
All Boundaries	61	93

It is apparent that relative judgment produces considerably greater accuracy than absolute categorized judgments at all boundaries.

D. Discussion

There is still no universally accepted practice for designating the difference threshold when an "equal to" judgment is permitted in a constant stimulus procedure. The .50 and .75 proportion uncertainty intervals have been presented as measures which are readily understandable. However, it should also be noted that these are probably conservative estimates, since it is known that when subjects are not permitted an "equal to" category, the majority of the "guesses" are correct. Conservatively then, it can be asserted that as the stimulus differences from the boundaries of the NEL system reach approximately ± 2 degrees.

observers can be expected to make approximately 50% correct discriminations, and at about ± 4 to 5 degrees, about 75% will be correct. Whether this is an acceptable operational error rate cannot here be stated, but it probably represents something near the limit of discriminable capacity for such stimuli. The larger error at the second boundary cannot at this point be explained by the writers.

The consistent superiority of the relative discrimination judgments to the absolute categorization procedure has a clear operational implication. If no mechanical assist device is given the PPI operator in measuring axis angle, and if a means for categorizing angular extent remains a requirement of target classification logic, then the two procedures could be combined. This could be done by placing near the scope examples of each of the boundary stimuli, which could then be used for comparison, discriminative judgment, and finally appropriate categorization.

E. Summary and Conclusions

To assess the accuracy limits of human judgments of the angular differences required in certain aspects of target classification by scanning sonar, a study was carried out utilizing the boundary angles between categories in the NEL angle classification system as standard stimuli and stimuli adjacent to them in 1 degree steps as variable stimuli.

The following conclusions can be drawn:

1. The .50 proportion uncertainty interval is at approximately ± 2 degrees and the .75 proportion uncertainty interval at about ± 4 to 5 degrees.
2. Boundary 2 produces a somewhat larger uncertainty interval than the other boundary stimuli.
3. No major degree of constant error at any boundary is found.
4. Compared with a previous study which required absolute categorized judgments of angular size, the relative judgment procedure used here proves much more accurate.
5. A combination of relative and categorizing judgments is indicated under certain operational assumptions.

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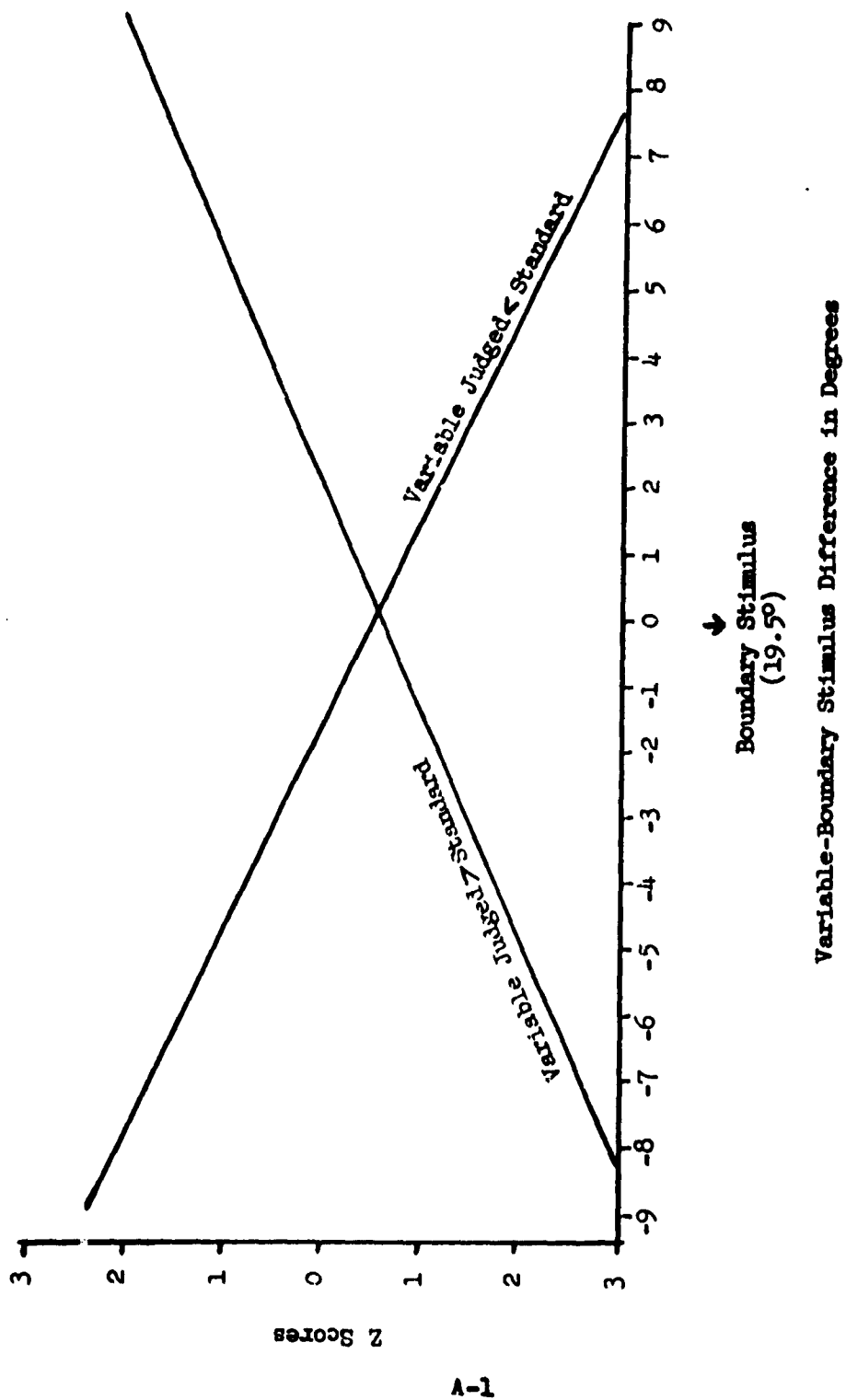
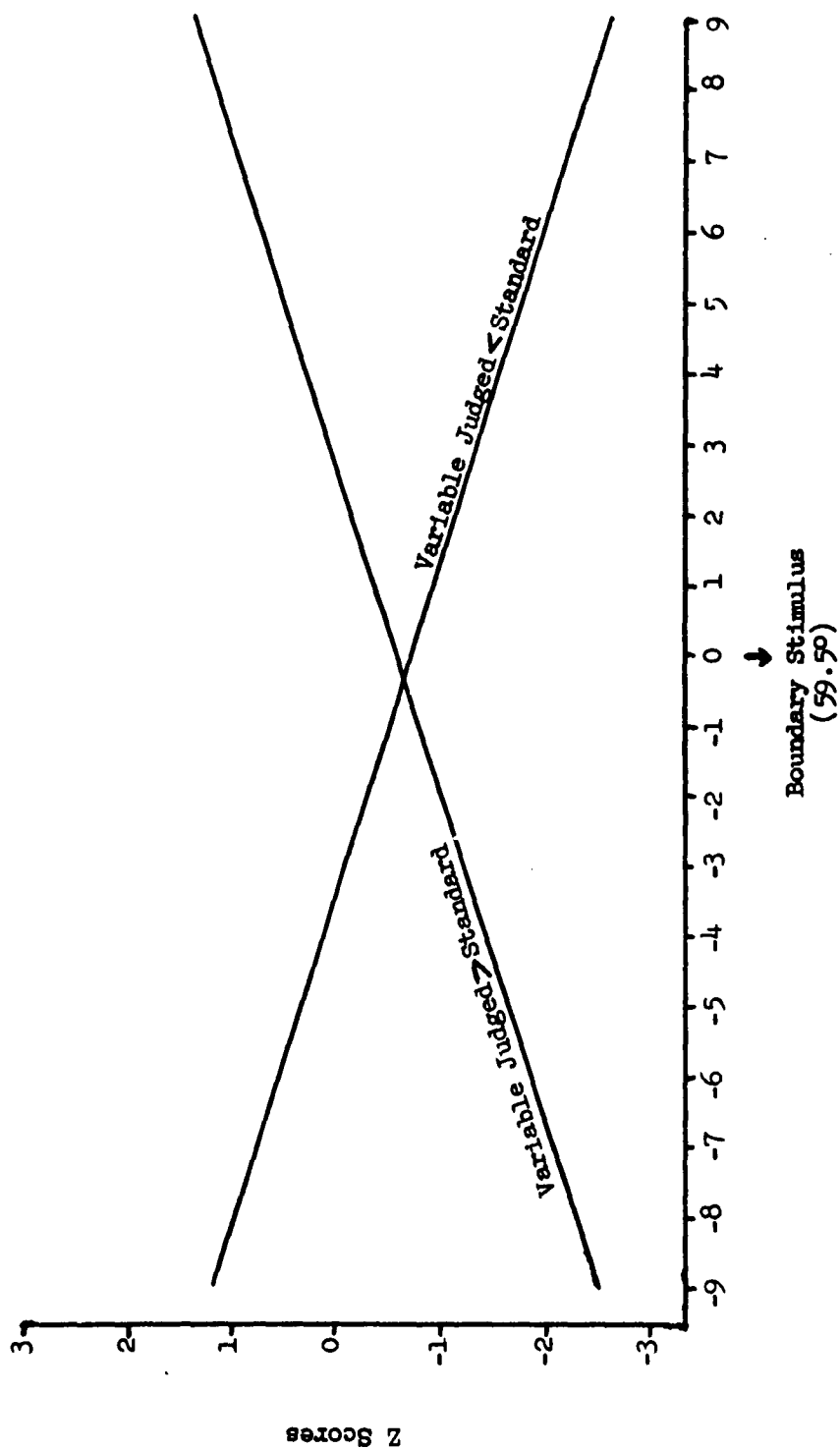
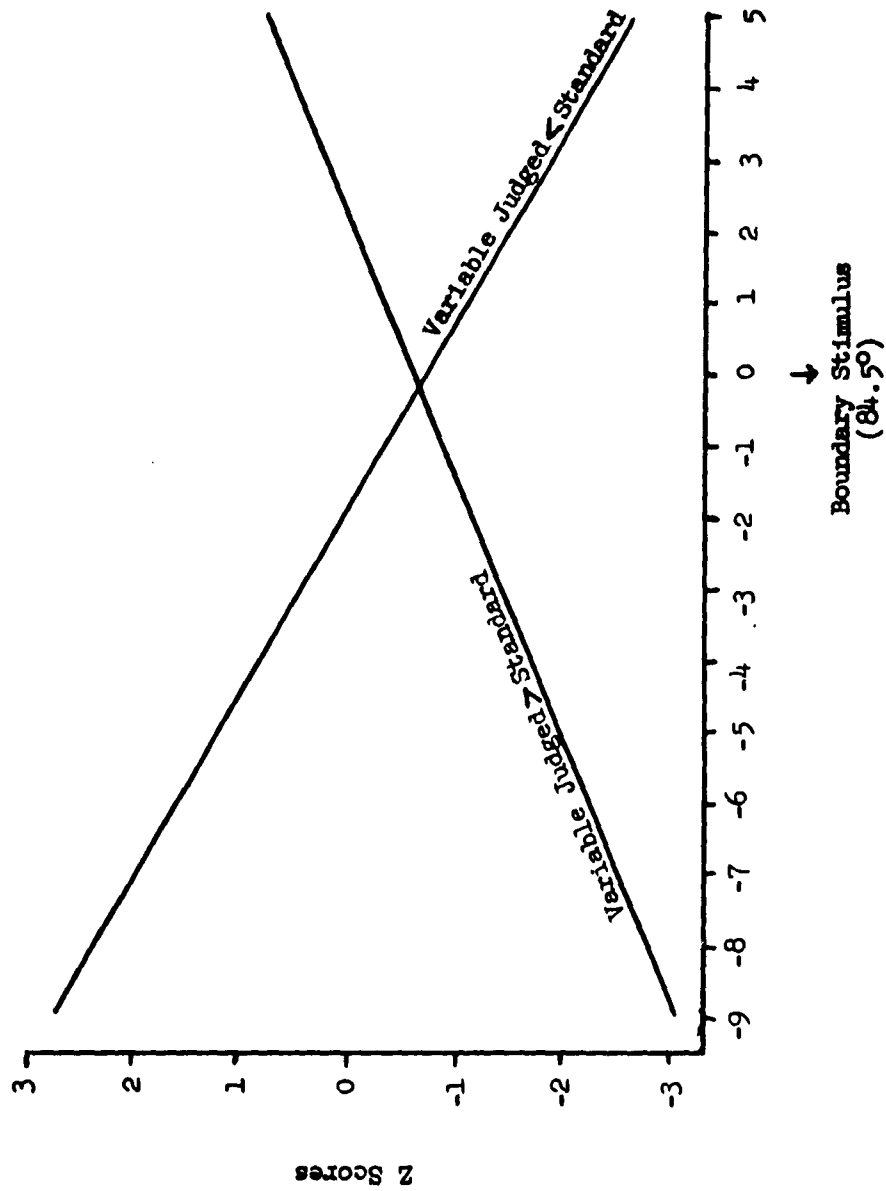


Fig. 1a. Average Z score equivalents of proportion of judgments greater and less.
Boundary 1



Variable-Boundary Stimulus Difference in Degrees

Fig. 2a. Average Z score equivalents of proportion of judgments greater and less.
Boundary 2



Variable-Boundary Stimulus Differences in Degrees

Fig. 4a. Average Z score equivalents of proportion of judgments greater and less.
Boundary $\frac{1}{4}$